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HEAP LEACHING FORUM
EXHAUST VENTING AT COAL MINE FACES
ENVIRONMENTAL MODELING AT THE NEW WORLD MINING DISTRICT
GRANITE QUARRYING TECHNOLOGY

Heap leaching discussed at roundtable



Placement and compaction of a soil liner and the placement of a geomembrane liner at a heap leach operation.

On Feb. 11, 2005, more than 20 mining professionals gathered in Elko, NV for a day-long roundtable discussion on heap leaching. Attendees included project managers, operators and environmental professionals. They represented 10 mining organizations. Knight Piésold sponsored the special event. Its seven representatives included three staff members from the company's Elko Operation, and one each from its Denver, Cajamarca (Peru) and Vancouver offices.

The roundtable format was chosen to allow people from the mining industry to share ideas and experiences in an open forum. Rather than presenting prepared talks, spontaneity was encouraged. This resulted in a lively and enjoyable discussion. Agenda items included:

- Facility siting and layout considerations.
- Role of geotechnical site investigations.
- Geotechnical design.
- Liner selection.
- Drainage and solution conveyance/collection.
- Solution and storm water ponds.
- Water balances.
- Contractor selection.
- Role of quality assurance in construction.
- Permitting issues and environmental considerations.

- Heap loading, cycle times and lift thickness.
- Problems.

Any one of these topics could have led to a daylong discussion. As would be human nature, discussions also led to related tangents, such as tailings storage facilities. In addition, lines were blurred between the topics, and discussions with related areas often filtered into the various subjects. Feedback forms filled out by the participants indicated that the event was beneficial and that additional roundtable discussions should be held in the future.

Knight Piésold personnel initiated each topic with a

Bryan Ulrich and Kerry Lahti

Bryan Ulrich, member SME, is vice president, Nevada Operations, with Knight Piésold and Co., 460 Silver St., Suite 106, Elko, NV 89801, e-mail bulrich@knightpiesold.com.

Kerry Lahti is senior associate with Knight Piésold and Co., Jr. Etan 124, Cajamarca, Peru, e-mail klathi@knightpiesold.com.

brief introductory comment. They either opened the topic for discussion or called on specific individuals to share their experiences with the group. This article provides a brief summary of the discussions that took place during the meeting. This is not meant to be an authoritative and complete compilation of information pertaining to heap leaching, but rather a summary of the discussions that took place.

Facility siting and layout considerations

Designing for closure is vital to the long-term success of any mining operation. So it is essential that mining facilities be situated as optimally as possible. Land ownership issues often dictate facility siting. Cognizance of property boundaries, ownership of adjacent lands and pit location play a central role in siting a mine's various facilities. This facility siting process often involves a design team that would include mine personnel and engineering consultants. A properly organized team can be equipped with the foresight to arrange all the facilities adequately.

During the early conceptual period of a project, the various facilities related to a mining project are often roughly sited, with predictions of future gold prices being used as a guideline for the placement of facilities. The group discussed the difficulty of accurately predicting gold prices. This factor can lead to facilities that become poorly situated in the future. Also, early in the life of a project, funds can be limited. This restricts the amount of work that is completed for optimizing the siting of the facilities.

Designing to allow some flexibility to changes in the metals market would have obvious advantages.

Role of geotechnical site investigations

The importance of a well-conceived geotechnical site investigation was discussed. Several operators spoke of poorly functioning facilities (not limited to the heap leach facilities) that could have been better designed and built if a proper geotechnical site investigation and engineer-

ing design had been completed at the inception of the work. An old adage was shared with the group: you pay for a site investigation whether you have one or not. Several anecdotes of poorly completed site investigations were shared with the group. Each offered a lesson on reasons to carry out an intelligently formulated site investigation.

The amount of time, energy and money spent on geotechnical investigations by the mining companies depends on the amount of information already available. When little information is available, the mines often rely on input from engineering consulting firms to provide reasonable guidelines for establishing the level of work necessary for the site investigation. The geotechnical engineer should establish a justifiable site investigation. And he or she should be able to offer an explanation of each feature of the investigation. Many mines complete risk analyses and audits for guidance in establishing the amount of investigation that should be required. The participation of a qualified heap leach facility designer would improve the results of such risk analyses and audits.

It was noted that the results of geotechnical site investigations infrequently alter the general layout of the facilities. Rather, the geotechnical design often must be completed to take unanticipated conditions into consideration. For example, soft soils may require removal from within the footprint area of a heap leach facility.

The early identification of material to use in the drainage layer should be a priority of the site investigation. This material can represent a major variable in the capital cost of the heap leach facility. The selection of a poorly functioning material can become an economic catastrophe to the long-term operation of a heap leach facility.

The materials in immediate contact with the geomembrane liner are critical to the proper operation of a heap leach facility, affecting solution recovery and slope stability. As such, it is imperative that these materials be identified early in the design process. Redesign steps may be necessary depending on the materials that are identified for use as soil liner and overliner (or protective layer).

Recontouring of the pad topography, for example, can be undertaken to overcome some of the difficulties associated with low interface shear strengths. Geosynthetic clay liners (GCLs) have been used in certain situations if insufficient low-permeability soil is available on the site. Designs using GCLs should be developed with considerations of its possible effects on slope stability. Facilities can also be designed using bentonite-amended soil. Decisions to use GCLs or bentonite amendment should be made recognizing possible physical and chemical changes to the clay due to the chemical constituents of the leachate solution.

There is little information to guide a mine owner in the proper way to conduct geotechnical site in-

An example of field reconnaissance activities related to heap leach facility siting studies. This one included a global positioning system survey.



Heap leach material being placed on a pad using a radial stacker.



vestigation. However, it is evident from the discussion that a well-developed investigation is imperative to the proper operation of a heap leach facility.

Geotechnical design

The quantification of geotechnical parameters and properties can greatly improve the operation of a heap leach facility. The permeability of the various materials involved plays a key role in the recovery of fluids. Operators typically apply leachate solutions at rates just below ponding thresholds of the ore. The heap and its underlying drainage system should be permeable enough to percolate the fluids through the heap. And the network of drainage pipes at the base of the heap should be designed to rapidly convey the fluids to the perimeter trenches/pond system.

Pore pressure buildup within the heap is counterproductive to metals recovery and it can jeopardize slope stability. It is, therefore, important that the solutions be allowed to exit the heap as efficiently as practicable. Only a small percentage of heap leach facilities have instrumentation such as piezometers installed. As such, it is not practical to make adjustments to the heap afterwards to correct for pore pressure buildup. And the geotechnical characteristics of the materials should be well understood beforehand to avoid such an occurrence.

Permeability testing of the ore can be beneficial in understanding the expected behavior of a heap leach facility. The permeability tests should be carried out to represent the range of conditions expected in the field. This would include tests on agglomerated material, aged material and materials confined under the pressures anticipated to be imposed by the heap.

Side slope leaching is carried out by a few of the operations present for the roundtable discussion. Such a

practice can lead to a buildup of solutions near the toe of the heap — an area where slope stability can be at its lowest. Operations where such a practice is carried out should be developed with consideration of its impacts on slope stability.

The resistance to sliding along a soil-to-geomembrane interface is often the controlling factor that dictates the stability of a heap leach facility. Proper characterization of this strength using the materials identified for use in the construction of the facility is critical to the geotechnical design of a heap leach facility. Tests should be carried out using the range of loads anticipated in the field, with materials compacted considering the density and moisture content specified for the project. Great care is necessary to correctly interpret the results of interface shear tests.

A sound geotechnical design can be an irreplaceable tool in establishing a priori the range of expected behaviors that a heap may exhibit during its life. This design would couple laboratory testing with modeling to assess slope stability as well as fluid movement through the heap.

A well-conceived geotechnical design can improve the long-term success of a heap leach facility. It can also help guide the way toward necessary alterations to the design.

Liner selection

The selection of an appropriate geosynthetic liner is crucial to the success of a heap leach facility. With heap heights continually on the rise, liner selection becomes more critical. Thicker high-density polyethylene (HDPE) geomembranes are often selected because they offer greater puncture resistance. However, alternatives to HDPE can also be considered. These include very-low-density polyethylene (VLDPE) and linear low-density

Solution delivery pipes and mounded heap material created by “fluffing” to reduce the effects of material compaction due to equipment traffic.



polyethylene (LLDPE). Load testing of the geomembrane with the site materials that will be placed on either side of the geomembrane can be beneficial in selecting an appropriate geomembrane to match the project requirements.

Textured geomembranes are used more often today because they provide a greater interface shear resistance with the adjacent soils when compared to smooth geomembranes. Welding techniques for textured geomembranes have improved, making their installation and quality assurance a more streamlined process. The cost of placing texturing the geomembrane depends on the process used to apply the texture. The performance of the textured geomembrane also depends on the manufacturing process. It was noted that texturing can result in a liner with reduced elongation characteristics.

Interpretation of laboratory interface shear tests us-

Placement of drainage material on a heap leach pad.



ing textured geomembrane must be completed with consideration of the integrity of the texturing as very little shearing may be required to erode the texturing.

The purpose of texturing in slope stability is to increase the frictional resistance at that soil-to-geomembrane interface to a point where a failure surface would be forced to pass through the soil rather than along the interface. If the texturing is eroded or sheared off at very low normal loads, the “useful” interface shear strength may be essentially the same as that determined for a smooth geomembrane.

Several precautions were stated for mining companies that are considering purchasing geomembranes from foreign manufacturers or Third World countries. Third party conformance testing before shipment is encouraged. An example of a heap leaching operation in Nevada that used such a troublesome geomem-

brane was shared with the attendees.

It was mentioned that geomembranes from different suppliers might be incompatible for welding. Different resins may not match sufficiently to allow an efficient weld to be made. Foreign manufacturers may use a wider variety of resins in making their geomembranes compared with those manufactured in the United States.

The selection of a geomembrane is vital to the success of a heap leach facility. The final decision in geomembrane selection should be made with adequate flexibility to allow for changes in the operation, such as increased ultimate heap height.

Drainage and solution conveyance/collection

The drainage layer is one of the most important features of a successful heap leach facility. One participant noted that a major heap leach facility had accumulated a significant inventory buildup, not because of a clayey ore, but due to poor drainage at the base of the heap.

On occasion, a cushion layer may be required between the drainage layer and the geomembrane. This would be especially common if the only appropriate drainage media includes large or angular particles. When such a cushion layer is not necessary, the terms “overliner” and “drainage layer” are often used interchangeably. Several comments were made regarding the characteristics of a desirable drainage layer.

There is considerable value in observing the placement of the overliner material. Observations during this process should include performance of the drainage pipes, especially at their couplings. This en-

sure no oversize or otherwise inappropriate material is placed on the liner.

Other observations included carefully checking for tears in the liner and monitoring the thickness of the layer. Wrinkles in the geomembrane can often be avoided by installing the liner during cooler weather, including the earlier parts of the day.

Attendees reported thicknesses of overliner ranging from 460 mm to 0.9 m (18 in. to 3 ft). Placement is done using scrapers, 777 Caterpillar haul trucks and low-ground-pressure dozers, and belly dumping trucks.

Compaction of the drainage layer should generally be avoided because the permeability of the layer can be reduced. This would reduce its ability to drain the leachate from the heap. It was noted that there is a current trend to compact material adjacent to drainage pipes. Engineers and owners need to consider this practice carefully because such an operation could decrease the ability of materials surrounding the pipes to allow fluids to flow into the drainpipes.

Some of the operators present prefer to have internal separations dividing the pads into smaller cells. These separations can be achieved with berms or trenches. Without such separations, it is difficult to make adjustments to account for operational experiences gained as the heap develops.

Solution and storm water ponds

There are some strides being made to avoid traditional freestanding solution ponds. Sumps and in-heap ponds are two of the options being used as alternatives. Cross-valley heaps can be used for in-heap solution storage, to avoid traditional ponds. For facilities using sumps, there are some difficulties that designers must overcome, including concrete-to-geomembrane tie-ins.

Special considerations are often required for designs that include concrete sumps. Concrete is often not accepted as being impermeable, necessitating an additional feature to achieve acceptance. For sites that are topographically favorable, tanks can be an acceptable alternative to sumps.

For facilities that include traditional ponds, designers and owners should consider operational aspects during the design process. For example, sedimentation buildup can create dead space in the pond. This decreases its capacity and necessitates a cleaning program. Pond cleaning operations may necessitate additional ponds.

In addition to environmental issues, sizing of the ponds should be made with consideration of a number of factors. These include storm events, the possibility of downtime or electrical outages, draindown time, pumping capacity and backup pumps.

Geotechnical laboratory testing of soils recovered during a site investigation showing flex wall permeability testing.



Water balances

The primary purpose of a water balance is to size ponds to accommodate operational volumes and storm-event volumes under a variety of operating and climatological scenarios. High-quality input is needed so that a reliable model is built. This may include ore properties as well as daily precipitation, temperature and evaporation data. Intense storm events may be the driving factor in the required sizing of a pond system. Heap loading plans should be as detailed as possible, as the phasing of heap construction can have a major impact on the predictions of the water balance. Modelers should coordinate with facility operators to ensure the model sufficiently reflects that way the owners will be operating the facility.

The use of a Monte Carlo type simulation for climatic forecasting may not be appropriate. Monte Carlo simulation uses a stochastic technique. This means that it uses random numbers and probability statistics to obtain forecasts. Since precipitation and evaporation influence each other, independent random generation of these two factors may be invalid.

In addition, a simple Monte Carlo simulation has been observed to be a poor predictor of the cyclical nature of these climatic factors. Instead, the use of historical data to create a statistical assessment of future conditions provides a better sense of reliability for such forecasts.

The impact of an extreme storm event should be assessed for any given month in the model. The consider-

Example of dust suppression and moisture conditioning of soil liner material at a heap leach operation.



ation of storm events occurring in quick succession should also be made as part of the water balance modeling efforts. Several stories of back-to-back storm events were shared among the participants, including such occurrences early in the operation of a facility.

Prolonged periods of drought should also be considered because the extreme lack of available solution may affect the project economics drastically. Through good prediction, it may be possible to store sufficient water to keep ahead of demand during periods of drought.

Water balances can range in complexity from simple to sophisticated. Mine owners should select the type of water balance model that best fits their needs based on the complexity of their operation as well as the level of risk they are willing to accept with the pond sizing.

Contractor selection

When selecting a contractor for the construction of

Drainage pipes at the base of a heap leach will assist in the recovery of leachate solutions.



a heap leach facility, it was noted that price should not be the primary driving factor. You are essentially selecting individuals. Staffing of construction jobs is of primary importance to the successful outcome of a construction project. People adjudicating the cost proposals of contractors should assess the résumés of the proposed superintendents and foremen. Having a trustful relationship with a contractor is beneficial to the construction process.

In times of economic upswings with metals prices also on the rise, contractors can become busy, making contractor availability a critical issue. Personnel selection can become an even more vital matter.

A cradle-to-grave approach with contractors and engineering consultants can be beneficial to a project.

Mining companies often move their staff from project to project. In such cases, the institutional knowledge sometimes resides only with the contractors and design engineers.

Role of quality assurance in construction

The role of construction quality control and assurance (CQA) is to ensure that the client's needs are met and that the intent of the engineering design and technical specifications are met. The CQA activities are the "eyes and ears" of the designer. Complete CQA coverage typically results in good construction documentation. It can also offer solutions for difficulties that may arise in the future, such as locating buried drainage pipes. High quality surveying is important for solving future problems. It also expedites the completion of the construction report.

Mention was also made of selecting qualified personnel to carry out the CQA work and that continuity of service providers can be beneficial. Some mines have general policies to award the CQA work to the designing firms, while others generally put this work out to bid.

Permitting issues and environmental considerations

Although the topic was not specific to closure, much of the discussion focused on closure issues. Attendees expressed the sentiment that heap leach facilities are generally less problematic to close than tailings facilities. However, several challenges still exist.

It was noted that the best engineering decisions for heap leach facilities are often also the best environmental decisions. Designing for closure is now commonplace. Most companies throughout the world work at or above the level of

the applicable existing environmental regulations. Wherever the facility is, guidelines such as those of the World Bank should be considered.

A few of the attendees had completed the closure and reclamation of a heap leach facility. In general, there is an effort toward constructing evapotranspiration (E/T) covers. This application has worked well in arid climates, especially once the draindown is managed.

Depending on the characteristics of the ore, the draindown period can be lengthy, or it can be quite short. Various models can be used to successfully guide closure issues regarding draindown. With good input parameters, a knowledgeable practitioner can make useful predictions that can help guide closure initiatives.

A study is being undertaken on behalf of the U.S. Environmental Protection Agency to assess the performance of various models. The results of this study may be useful in establishing realistic closure bonds for heap leach facilities.

Column leach tests are used to generate data on the leaching characteristics of an ore, and to allow prediction of the recovery/time curves. Parameters used to model the draindown of a heap are often based on the results of column tests. Although these tests are typically carried out under low stress conditions, compacting the ore into the test columns at various densities to represent various burial depths can approximate the effects of deep burial. This practice can improve the outcome of the modeling efforts.

Heap leach facilities are continually designed with greater ultimate heights. Designers and operators must become more aware of the several affects that such a practice entails. Among these considerations would be the increased draindown time required before closing and reclaiming the facility, including the associated financial implications.

Heap loading, cycle times and lift thickness

Truck loading is the most common method of delivering ore to a heap leach facility. Compaction issues are a primary concern with the use of large mine haul trucks. Ripping and "fluffing" using backhoes or dozers, especially in haul roads, is typical. One operator stated that his mine has instituted a program to isolate finer materials in the central areas of a heap. This would improve slope stability conditions, as elevated phreatic surfaces and materials of lower shear strength would be isolated in areas away from the outer slopes.

The issue of optimal lift height was raised. This dimension depends on the particular properties of the ore and on the operating considerations. At times, the lift height is also selected to minimize compaction of the ore due to trafficking by the loading equipment. When feasible (economically or for construction purposes), the use of a conveyor system is one way to avoid excessive compaction.

Pad designs that are developed based just on the to-

Example of a poorly performing heap leach facility. Photo shows sloughing of heaped materials due to elevated fluid levels within the heap.



tal tonnage of the material to be stacked may be inadequate. Pads should be designed considering areas specifically available for leaching, as opposed to stacking, aging, pre-wetting or other such activities. This is especially important for the upper lifts where the top surface area decreases.

Problems

The attendees discussed several types of problems in heap leach design. Insufficient overliner placement was noted to cause damage to drainage pipes. Soil liner material that is too wet in the borrow area is a typical difficulty during construction, a condition that should be foreseeable.

There was some discussion on the use of interlift liners. When ore is especially clayey, or when the drainage layer at the base of the heap leach facility is insufficient to drain solutions freely, the use of liners and/or drains between lifts can be considered. These operations are sometimes useful, but their success depends on the nature of the materials involved. Engineering analyses usually indicate that a well-constructed liner and complete drainage system is needed to ensure the success of interlift liners.

Despite these predictions, there have been some noted successes where facilities have installed only drainage piping between lifts. Installing an interlift liner and drain may preclude the lower lifts from future leaching or rinsing. Alternatively, several companies are investigating the feasibility of installing an irrigation system beneath the interlift liner.

Closing

The roundtable discussion was a considerable success. It offered heap leach operators, project managers and environmental professionals an open forum in which to express their thoughts and gain from the experiences of others.

As the sponsor of the event, Knight Piésold has made the decision to make this a recurring event. The next roundtable discussion will be held in Elko early in 2006. It will focus primarily on tailings storage facilities. ■ (The photos for this article are not a product of the roundtable discussion. They are Knight Piésold's file photos captured during the past several years.)